



U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves

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Review and
Update



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric
Administration



U.S. DEPARTMENT OF INTERIOR
U.S. Geological Survey

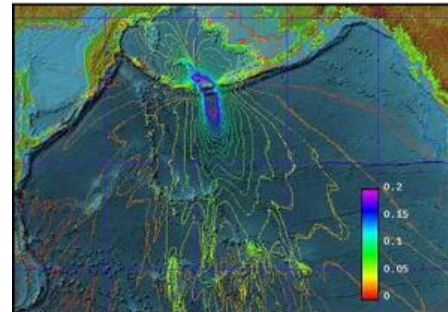
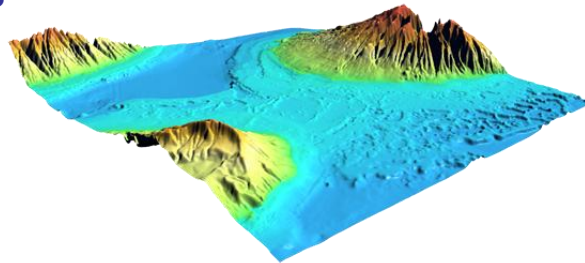


US Tsunami Hazard Assessment



- National Science and Technology Council released the report
 - *Tsunami Risk Reduction for the United States: A Framework for Action, December 2005*
 - Develop tsunami hazard and risk assessments for all coastal regions of the US states and territories
- NTHMP provides the organizational framework needed to execute the President's tsunami initiative
 - NOAA was asked to take the lead in performing the assessment
 - NOAA's National Geophysical Data Center (NGDC) catalogs information on global historic tsunamis
 - U.S. Geological Survey (USGS) conducts research on earthquake hazards facing all of the U.S. states and territories
 - NGDC and USGS partnered together to conduct the first tsunami hazard assessment for the US states and territories

- Probabilistic tsunami hazard analysis
 - Historical and Prehistorical (paleo) tsunami data
 - Quantitative probabilistic models of local and far-field tsunami sources (earthquake, landslide, volcano)
 - High-resolution DEMs (topography, bathymetry, tidal information)
 - Numerous propagation and inundation simulations for tsunami sources



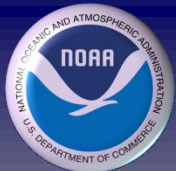
- Goal of the *first phase* of the National Tsunami Hazard Assessment
 - Qualitative assessment of the hazard at the state level



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Known Historical Record

NOAA/NGDC Historical Tsunami Database



- **Global Historic Tsunami Database -**
 - Source event (time, location, magnitude)
 - Runup locations where tsunami waves were observed (water heights, arrival times, wave periods)
 - Damage, deaths, injuries from the source and the tsunami
- **Variety of Data Sources**
 - Tide Gauge Observations, Reconnaissance Reports
 - Data catalogues: Tsunami, Earthquake, Volcano, Storms
 - Journal articles, Newspaper reports, Ship's Logs, Diaries, Personal Accounts
- **Tsunami Event Validities**
 - **High (validity 3-4)**
 - recorded on seismograph and tide gauge
 - prior to instrumental recordings – Reported by many reliable and independent sources
 - many reports of deaths, damage, and observations of waves in many locations
 - **Low (validity 0-2)**
 - reported to be earthquake-caused, but not listed in local earthquake catalogs
 - prior to instrumental recordings, described by only one source
 - meteorologically caused



New Approach of examining the Historical Tsunami Record



- Tsunami source events affecting the US and runups were reviewed for accuracy
 - Check original sources
 - Crosscheck with earthquake catalogs
 - Crosscheck with hurricane catalogs
- Events were selected for further examination
 - Not meteorologically caused
 - Validity 3 or 4
 - Runup not flagged as doubtful or meteorologically caused
 - Waves reported on inland waters such as Lake Erie or Roosevelt Lake were not counted
 - Tsunamis in Puget Sound and in bays in Alaska were counted
 - All dates were included - 1690 Virgin Islands earliest report



New Approach of examining the Historical Tsunami Record--contd



- Count tsunami events affecting each state
 - Bin tsunami events based maximum measured runup
 - $0.01 \text{ m} \leq \text{runup} \leq 0.5 \text{ m}$
 - $0.5 \text{ m} < \text{runup} \leq 1.0 \text{ m}$
 - $1.0 \text{ m} < \text{runup} \leq 3.0 \text{ m}$, and
 - $3.0 \text{ m} < \text{runup}$
- Tsunami event could be counted in several states
 - 1952, 1960, 1964, etc.
- Although not a vulnerability or risk assessment
 - Examine the severity of tsunamis by counting total number of deaths and dollar damage due to tsunamis in each state



Results – Tsunami event runups by state and region



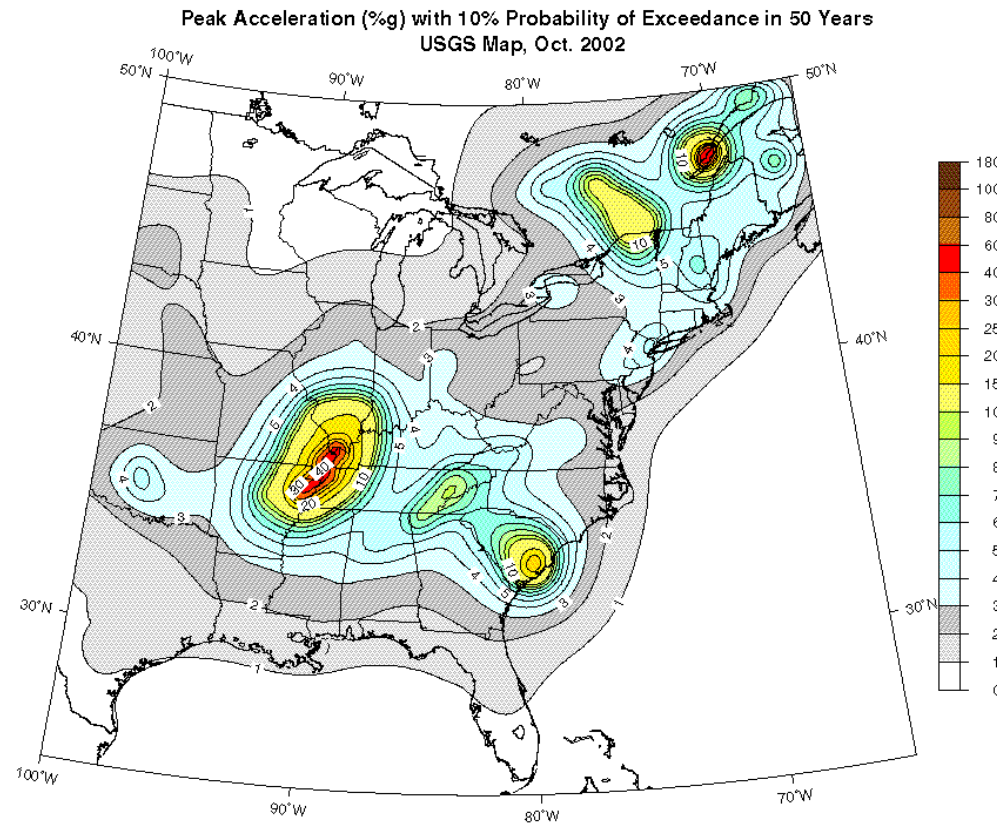
Table 2-1.

Tsunami events, total number of runups, deaths, and dollar damage by State and region from the NOAA/NGDC tsunami database. Dollars have not been adjusted for inflation. See Section 2.2.3 for an explanation of the counts. For more information on specific events, access the online database at http://www.ngdc.noaa.gov/hazard/tsu_db.shtml.

Location (and year of first confirmed report)	Total number of tsunami events with any observed runup	Events with undetermined runup heights	Events with runups 0.01 to 0.5 m	Events with runups 0.51 to 1.0 m	Events with runups 1.01 to 3.0 m	Total number of runups for all tsunami events	Reported deaths	Million dollars damage reported
U.S. Atlantic Coast								
Maine (1929)	1	1				3		
New Hampshire (1929)	1	1				1		
Massachusetts (1929)	1	1				2		
Rhode Island (1929)	2	1	1			3		
Connecticut (1964)	1	1				1		
New York (1895)	2	1	1			7		
New Jersey (1918)	6	3	2	1		8		
Pennsylvania								
Delaware								
Maryland (1929)	1		1			1		
Virginia								
North Carolina								
South Carolina (1886)	2	1	1			2		
Georgia								
Florida (1886)	4	3	1			5		
Atlantic Coast Totals	21	13	7	1	0	33	0	\$0
U.S. Gulf Coast								
Florida								
Alabama								
Mississippi								
Louisiana								
Texas (1918)	1	1				1		
Gulf Coast Totals	1	1	0	0	0	1	0	\$0
Puerto Rico and Virgin Islands								
Puerto Rico (1867)	9	1	3	2	2	1	33	142
Virgin Islands (1860)	7	2	1	1	1	2	15	30
PR & VI Totals	16	3	4	3	3	3	48	172
U.S. West Coast								
Washington (1891)	21	2	13	1	4	1	64	1
Oregon (1854)	18	1	12	1	2	2	62	5
California (1812)	75	5	48	9	8	5	425	19
West Coast Totals	113	8	73	11	13	8	550	24
U.S. Pacific Island Territories								
Guam (1849)	15	2	10	1	1	1	23	1
Northern Mariana (1990)	1	1					1	
American Samoa (1837)	56	9	40	4	3		60	
Pacific Is. Totals	72	12	50	5	4	1	84	1
Alaska (1737) Totals	81	6	49	4	6	16	352	222
Hawaii (1812) Totals	114	0	79	6	11	18	1592	326
AMERICAN TOTALS	419	43	262	30	38	46	2661	746

USGS Earthquake Hazards Assessment

Earthquake databases can be used to extend the historical tsunami record backward in time





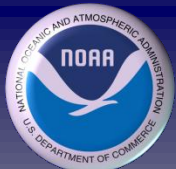
Local earthquake sources—USGS

Earthquake Probabilities



Non-Subduction Zones

State/Territory	Earthquake with Mag > 6.5 in 500 years within 50 km of coast	Earthquake with Mag > 6.5 in 5000 years within 50 km of coast	Historical maximum magnitude observed nearshore or offshore	Comment
U.S. Atlantic Coast				
Maine	<3%	<30%	<6	
New Hampshire	<3%	<30%	<6	
Massachusetts	<3%	<25%	<6	
Rhode Island	<2%	<15%	<6	
Connecticut	<2%	<30%	<6	
New York	<4%	<30%	<6	
New Jersey	<4%	<30%	<6	
Pennsylvania	<3%	<15%	<6	
Delaware	<3%	<15%	<6	
Maryland	<2%	<15%	<6	
Virginia	<1%	<4%	<6	
North Carolina	<1 to 5%	<5%	<6	
South Carolina	<35%	100%	7.3	1886 Charleston, non-destructive tsunami
Georgia	<1%	<10%	<6	
Florida	<1%	<3%	<6	
U.S. Gulf Coast				
Florida	<1%	<3%	<6	
Alabama	<1%	<4%	<6	
Mississippi	<1%	<5%	<6	
Louisiana	<1%	<5%	<6	
Texas	<1%	<4%	<6	



Local earthquake sources—USGS Earthquake Probabilities



Subduction Zones

State/Territory	Non-subduction earthquake with mag > 6.5 in 500 years within 50 km of coast	Subduction zone event with mag > msubduct in 500 years within 150 km of coast	Maximum magnitude observed or estimated for nearshore or offshore	Comment
Puerto Rico and the Virgin Islands, msubduct = 7.5				
Puerto Rico	100%	~100%	7.5	1918 Mona Passage, severe tsunami**
Virgin Islands	100%	~100%	7.5	1867 Virgin Islands, severe tsunami
Pacific Coast--Cascadia, msubduct = 8.1				
Washington	30% to 90%	~100%	9+	1700 Cascadia, severe tsunami
Oregon	10% to 100%	~100%	9+	1700 Cascadia, severe tsunami
California	100%	~100%	9+	1700 Cascadia, severe tsunami
Pacific Coast--Alaska, msubduct = 7.5				
Alaska	100%*	~100%	9.2	1964 Alaska, severe tsunami
Western Pacific, msubduct = 7.8				
Guam	N/A	~100%	7.8	1993 Guam, non-destructive tsunami
Northern Mariana	N/A	~100%	7.8	1993 Guam, non-destructive tsunami
American Samoa	N/A	~100%	8.5	1917 Northern Tonga trench, moderate tsunami
Alaska calculation for mag>6.5 includes subduction interface events				
*Events as large as magnitude ~8 are estimated in the Puerto Rico trench				

Hawaii, Southern California, and Arctic Coast of Alaska

State/area	Mag > 6.5 in 500 years within 50 km of coast	Mag > 7.5 in 500 years within 50 km of coast	Maximum magnitude observed or estimated for nearshore or offshore	Comment
Hawaii and Southern California				
Hawaii	~100%	~100%	7.9	1868 Ka'u district, severe tsunami
Southern California	~100%	~100%	7.1	1927 Lompoc, moderate tsunami
Arctic Coast—Alaska				
Alaska	<1%	N/A	<6	Arctic coast rated no tsunami risk by Alaska



Qualitative Tsunami Hazard Assessment



Table A. Qualitative tsunami hazard assessment based on NGDC and USGS databases.

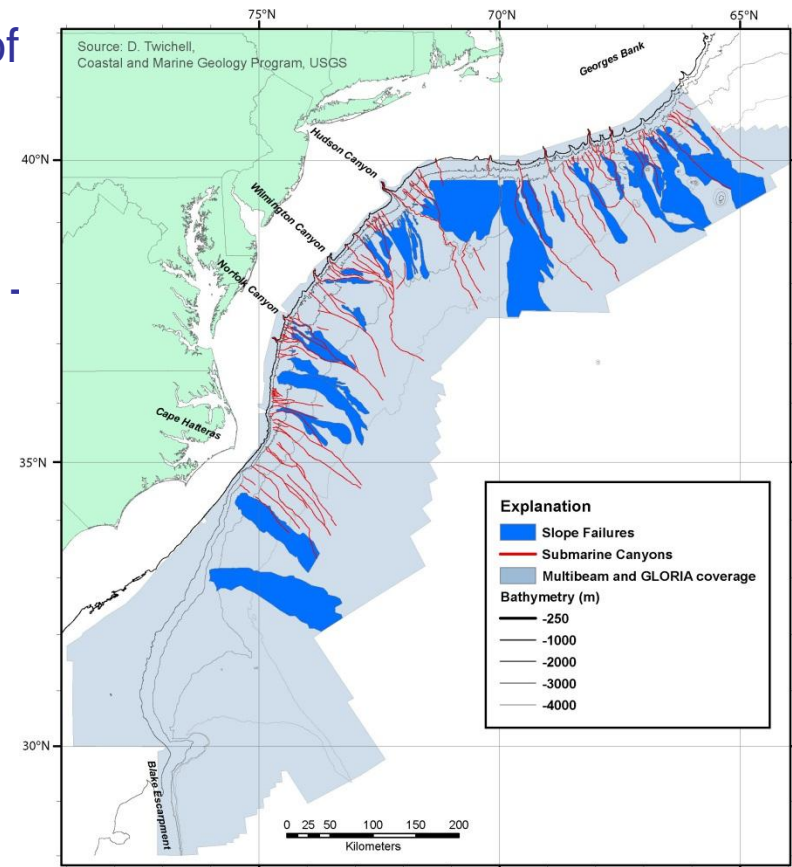
<i>Region</i>	<i>Hazard based on runups</i>	<i>Hazard based on frequency</i>	<i>Hazard based on local earthquakes</i>	<i>Number of reported deaths</i>
U.S. Atlantic coast	Very low to low	Very low	Very low to low	None
U.S. Gulf coast	Very low	Very low	Very low	None
Puerto Rico and the Virgin Islands	High	High	High	172
U.S. west coast	High	High	High	25
Alaska	Very high	Very high	High	222
Hawaii	Very high	Very high	High	326
U.S. Pacific island territories	Moderate	High	High	1

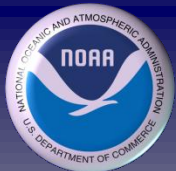


Gaps in the U.S. Tsunami Hazard Assessment



- Non-earthquake sources
 - Frequency of subduction zone earthquakes far exceeds frequency of other sources in the Pacific – have little effect
 - Volcano collapse and submarine landslides along the U.S. East Coast - could have an effect
- Atlantic Basin Earthquake sources
 - Earthquake magnitude and recurrence near the Iberian Peninsula
 - Northern edge of the Caribbean plate west of Hispaniola
- Pacific Basin
 - Earthquake generated landslides in Southern California





Next Steps

USA Tsunami Hazard and Risk Assessment

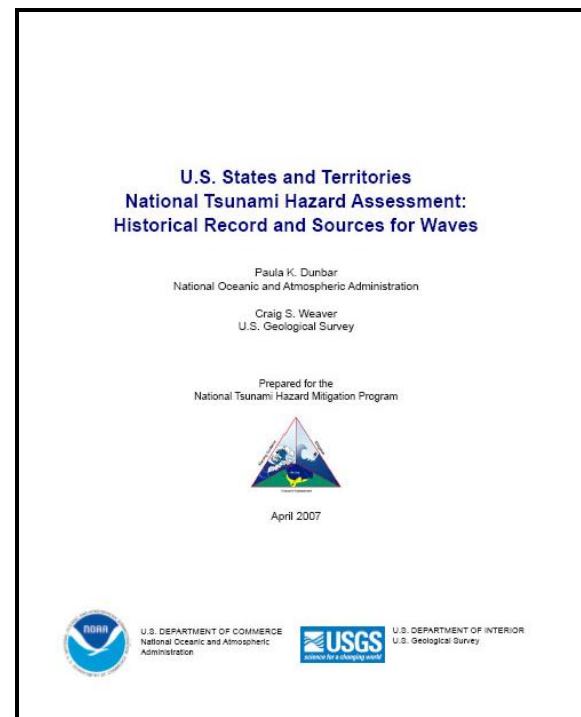


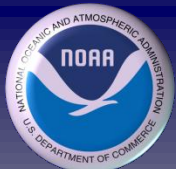
- Hazard Assessment – Document is available via NGDC and NTHMP websites:

<http://www.ngdc.noaa.gov/hazard/tsu.shtml>

<http://nthmp.tsunami.gov/>

- Hazard Assessment will be a dynamic document – updated with new research
- Vulnerability Assessment – future effort
 - NOAA working with FEMA (exposure), NIST (building standards) and others
 - Location and distribution of assets at risk (people, homes, buildings, utilities)
 - How easily the assets and people are damaged

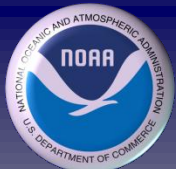




Tsunamis affecting U.S. 2007-2012



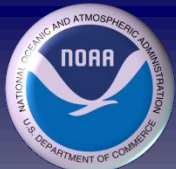
- ❖ 21 events – 18 earthquakes, 2 eruptions, 1 unknown cause
 - 625 US runups – 291 tide gauge, 220 field survey, 94 eyewitness, 20 DART
 - >3 m runups: 2008 (Maine), 2009 Samoa – A. Samoa
 - 1-3 m runups: 2009 Samoa – A. Samoa, 2010 Chile – Calif., 2011 Tohoku – Alaska, Calif., Hawaii, Oregon, N. Mariana Is
 - **2009 Samoa – 34 deaths, \$126 million - A. Samoa**
 - **2010 Chile - \$3 million - California**
 - **2011 Tohoku – 1 death, \$55 million – Calif., \$31 million - HI**



Updated Results – Tsunami event runups by state and region



Location (and year of first confirmed report)	Total Events	Un-deter- mined	0.01 to 0.5	0.51 to 1.0	1.01 to 3.0	> 3.0	Total runups	Reported Deaths	Estimated damage reported
Maine	2	1				1	7		
New Hampshire (1929)	2	1	1				2		
Massachusetts (1929)	1	1					2		
Rhode Island (1929)	2	1	1				3		
Connecticut (1964)	1	1					1		
New York (1895)	2	1	1				7		
New Jersey (1918)	6	3	2	1			8		
Pennsylvania									
Delaware									
Maryland (1929)	1		1				1		
Virginia									
North Carolina									
South Carolina (1886)	2	1	1				2		
Georgia									
Florida (1886)	4	3	1				5		
Atlantic Coast Totals	23	13	8	1	0	1	38	0	\$0
Florida									
Alabama									
Mississippi									
Louisiana									
Texas (1918)	1	1					1		
Gulf Coast Totals	1	1	0	0	0	0	1	0	\$0
Puerto Rico (1867)	10	2	3	2	2	1	34	142	\$4
Virgin Islands (1690)	9	2	3	1	1	2	18	30	
PR & VI Totals	19	4	6	3	3	3	52	172	\$4
Washington (1891)	26	1	18	2	4	1	92	1	\$2
Oregon (1854)	28		22	1	3	2	92	5	\$1
California (1812)	85	5	58	9	8	5	585	20	\$75
West Coast Totals	139	6	98	12	15	8	769	26	\$78
Guam (1849)	16	2	11		2	1	26	1	
Northern Mariana (1990)	8	1	6		1		9		
American Samoa (1837)	66	10	47	5	3	1	293	34	\$125
Pacific Is. Totals	90	13	64	5	6	2	328	35	\$125
Alaska (1737) Totals	95	7	60	5	7	16	433	222	\$122
Hawaii (1812) Totals	127	2	91	5	11	18	1681	290	\$90
AMERICAN Totals	494	46	327	31	42	48	3302	745	\$419



Possible Changes to the Qualitative Tsunami Hazard Assessment



Table A. Qualitative tsunami hazard assessment based on NGDC and USGS databases.

<i>Region</i>	<i>Hazard based on runups</i>	<i>Hazard based on frequency</i>	<i>Hazard based on local earthquakes</i>	<i>Number of reported deaths</i>
U.S. Atlantic coast	Very low to low	Very low	Very low to low	None
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